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Erratum: $h \to \gamma\gamma$ in $\mathrm{U}(1)_R$-lepton number model with a right-handed neutrino

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We found a sign error in our numerical code in incorporating the value of $\sin\alpha$. Earlier, in our code everywhere we used $\sin\alpha = +S_{42}$, whereas the relation should be $\sin\alpha = -S_{42}$ as correctly mentioned just before equation (B.10) of our published paper [1].

In addition, we missed out on a factor symmetric under $i \leftrightarrow j$ in the expression for ζ'_{ij} in equation (B.8). This factor would also show up in the expressions for η'_{ij} and ξ'_{ij} in equation (B.11) in terms of which ζ'_{ij} was expressed in equation (B.10). Note that, for identical neutralinos in the final state $(i = j)$, the partial decay width shown in equation (B.9) would have an associated $1/2$ factor.

The sign error is crucial as it leads to a much smaller value of the Higgs coupling to neutralinos thus resulting in a minuscule contribution to invisible and total decay width of the Higgs boson, in contrast to what reported earlier [1] for large neutrino Yukawa coupling ($f \sim \mathcal{O}(1)$) case. This in turn implies a significant relaxation of the parameter space, in particular, in the form of opening up regions with low values of $\tan\beta$. Expectedly, this leads to significantly different predictions for $\mu_{\gamma\gamma}$, which, collectively, now conform better to its experimentally observed trend. The modified figures are given below with necessary explanations. We have now also included the bottom quark and bottom squark (we considered $m_{\tilde{b}} \equiv m_{\tilde{t}}$) contributions in the loop processes $h \to gg$ and $h \to \gamma\gamma$.

Note that the $g_{hW^+W^-}$ coupling, shown in the upper left panel of figure 1 is almost Standard Model (SM)-like since we are essentially working in the decoupling limit. This

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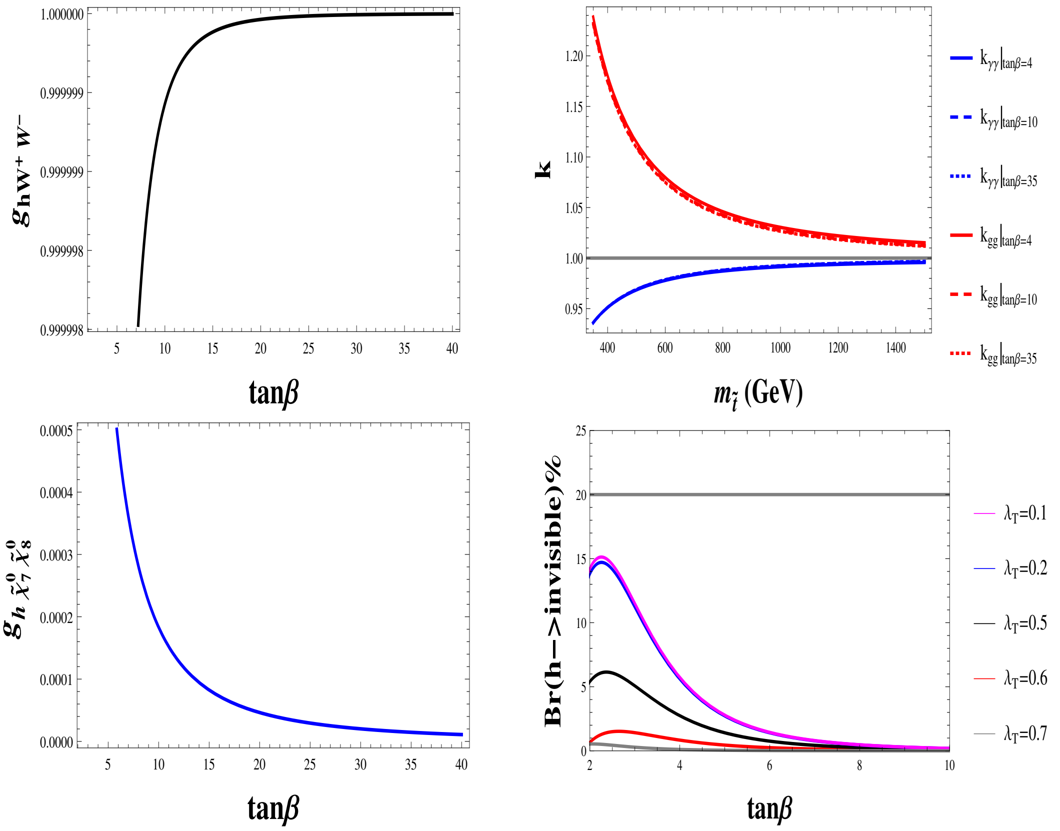

Figure 1. Modified versions of the figures 3 (left), 5 (right), 6 (below-left) and 8 (below-right) of reference [1]. All other relevant parameters are set at the values mentioned in reference [1].

implies that the W-loop contribution in the $h \to \gamma\gamma$ process remains almost unchanged with varying $\tan\beta$. This is also manifested in the upper right panel of figure 1 where the variations of $k_{\gamma\gamma}$ with $m_{\tilde{t}}$ are almost independent of $\tan\beta$. The relative sign in the Higgs-neutralino-neutralino coupling also implies a significantly smaller value of $g_{h\tilde{\chi}^0_7\tilde{\chi}^0_8}$ when compared to figure 6 of reference [1] (shown in lower left panel of figure 1). This in turn means that the partial decay widths of the Higgs boson to these light neutralino states are small. Naturally, no constraint can be drawn from the total decay width of the Higgs boson (figure 7 of reference [1] does no longer hold) and a comparatively larger value of $\mu_{\gamma\gamma}$ can be expected. We also present the modified version of figure 8 of reference [1] in the lower right panel of figure 1. It is clear that the presence of a bino-like light neutralino state is not yet constrained from the invisible decay width of the Higgs boson in our scenario with all the curves staying well below the experimentally derived upper bound of $\sim 20\%$ for the invisible branching fraction of the Higgs boson.

In figure 2 we show the contours of M_h and $\mu_{\gamma\gamma}$ in the $m_{\tilde{t}} - \tan\beta$ plane. For relatively low values of the top squark mass, an increased cross section for the resonant Higgs boson production through gluon fusion enhances $\mu_{\gamma\gamma}$. On the other hand, $\mu_{\gamma\gamma}$ is almost insensitive to $\tan\beta$ for $\tan\beta \gtrsim 15$. This is because $hb\bar{b}$ coupling (which controls the total decay width of the Higgs boson in a significant way) becomes independent of $\tan\beta$ for larger values of

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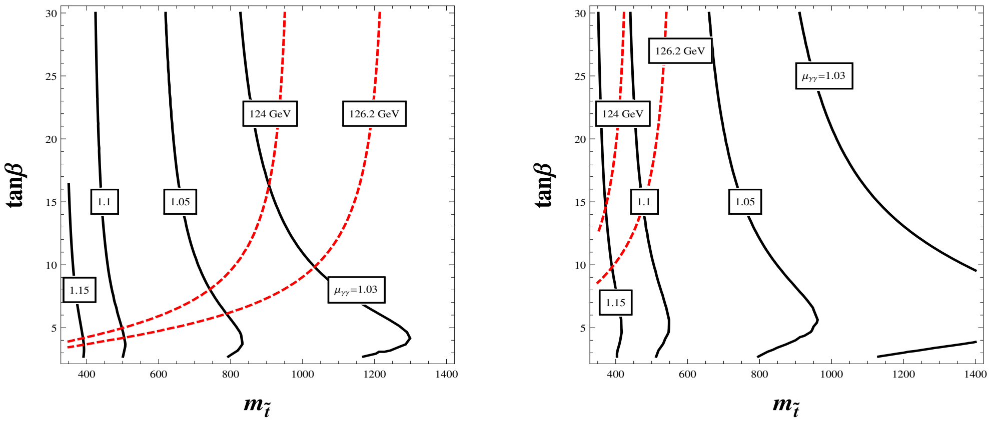

Figure 2. Modified versions of figures 9 and 10 of reference [1]. Note that contrary to reference [1], no constraint on the parameter space (more explicitly, on $\tan\beta$) can be obtained from the invisible decay width of the Higgs boson. All other relevant parameters are set at values mentioned in figures 9 and 10 of reference [1].

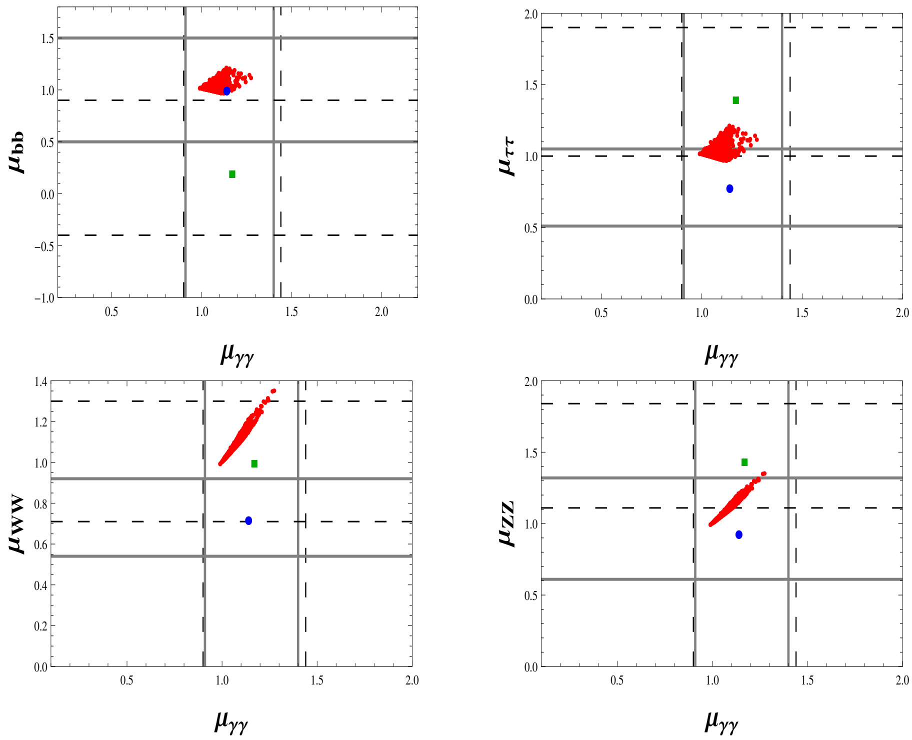

Figure 3. Modified version of figure 11 of reference [1]. The parameters are varied in the same range as discussed in reference [1]. All the points now satisfy the constraint from invisible decay width of the Higgs boson in contrast to figure 11 of reference [1].

this parameter. The relative signal strengths for $f \sim \mathcal{O}(1)$ case are shown in figure 3. The spreads in the upper two plots in figure 3 are due to the variation in the parameter f, which affects μ_{bb} and $\mu_{\tau\tau}$ whereas μ_{WW} and μ_{ZZ} remain unaffected. Finally, the $\mu_{\gamma\gamma}$ values should now be 1.07, 1.11, 1.11 for BP-1, BP-2 and BP-3, respectively in table 3 of reference [1].

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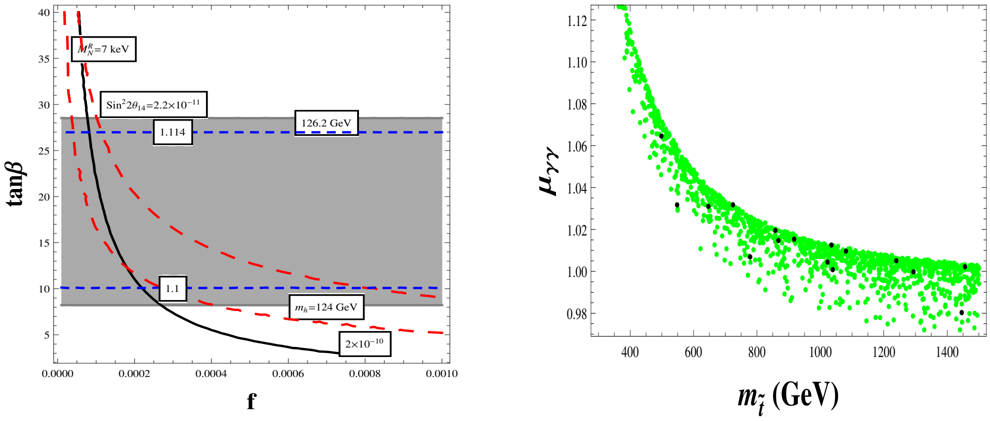

Figure 4. Modified versions of figures 12 and 13 of reference [1].

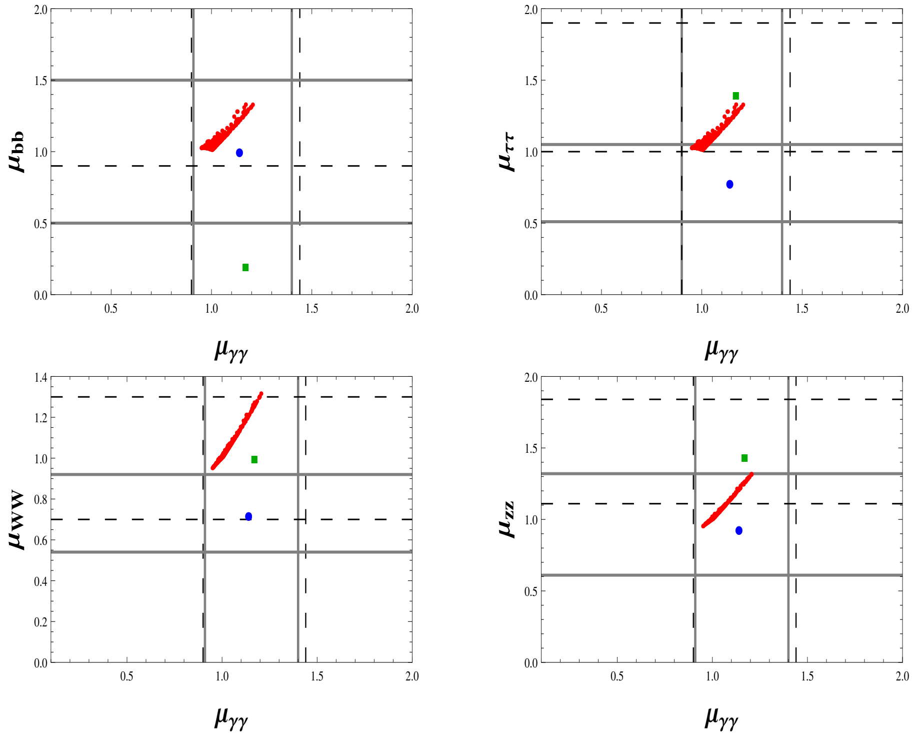

Figure 5. Modified version of figure 14 of reference [1].

For $f \sim \mathcal{O}(10^{-4})$, the overall conclusion remains intact with minor changes in the details. In the left panel of figure 4, we show the contours of the Higgs mass, along with the mass and active-sterile mixing of the sterile neutrino dark matter consistent with the 3.5 keV line. The scatter plot given in the right panel of figure 4 shows the variation of $\mu_{\gamma\gamma}$ with top squark mass. With increasing top squark mass, $\mu_{\gamma\gamma}$ approaches the SM value of 1 before going below the same with further increase on top squark mass. The relative signal strengths are shown in figure 5 for $f \sim \mathcal{O}(10^{-4})$. The corresponding $\mu_{\gamma\gamma}$ should now be 1.07, 1.06, 1.06 for BP-4, BP-5 and BP-6, respectively in table 4 of reference [1].

Finally, equations in (B.8) and (B.11) should now read

$$\begin{aligned}
\zeta'_{ij} = {} & S_{41}\left[\frac{g'}{g}\frac{N_{i1}N_{j6}}{2}+\frac{\lambda_S}{g}\frac{N_{i2}N_{j5}}{\sqrt{2}}-\frac{N_{i3}N_{j6}}{2}+\frac{\lambda_T}{g}\frac{N_{i4}N_{j5}}{\sqrt{2}}-\frac{f}{g}\frac{N_{i7}N_{j8}}{\sqrt{2}}\right]\epsilon_i \\
& +S_{42}\left[\frac{N_{i3}N_{j8}}{2}-\frac{g'}{g}\frac{N_{i1}N_{j8}}{2}-\frac{f}{g}\frac{N_{i6}N_{j7}}{\sqrt{2}}\right]\epsilon_i+S_{43}\left[\frac{\lambda_S}{g}\frac{N_{i5}N_{j6}}{\sqrt{2}}\right]\epsilon_i \\
& +S_{44}\left[\frac{\lambda_T}{g}\frac{N_{i5}N_{j6}}{\sqrt{2}}\right]\epsilon_i+(i\leftrightarrow j) \qquad (1)
\end{aligned}$$

and

$$\begin{aligned}
\eta'_{ij} &= \left[\frac{g'}{g}\frac{N_{i1}N_{j6}}{2}+\frac{\lambda_S}{g}\frac{N_{i2}N_{j5}}{\sqrt{2}}-\frac{N_{i3}N_{j6}}{2}+\frac{\lambda_T}{g}\frac{N_{i4}N_{j5}}{\sqrt{2}}-\frac{f}{g}\frac{N_{i7}N_{j8}}{\sqrt{2}}\right]\epsilon_i+(i\leftrightarrow j), \\
\xi'_{ij} &= \left[\frac{g'}{g}\frac{N_{i1}N_{j8}}{2}+\frac{f}{g}\frac{N_{i6}N_{j7}}{\sqrt{2}}-\frac{N_{i3}N_{j8}}{2}\right]\epsilon_i+(i\leftrightarrow j). \qquad (2)
\end{aligned}$$

We conclude that in the $f\sim\mathcal{O}(1)$ case, no constraint can be obtained for $\tan\beta$ from the invisible and total decay widths of the Higgs boson. This opens up the corresponding parameter space ($\tan\beta$) when compared to our published reference [1]. We would also like to note that because of the reduction of the total decay width of the Higgs boson as compared to reference [1], the values of $\mu_{\gamma\gamma}$ as obtained in this model are more consistent with the recent observations from both the ATLAS [2] and the CMS [3] collaborations.

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